

*FROM MOLECULAR TO MOLAR:
A PARADIGM SHIFT IN BEHAVIOR ANALYSIS*

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A paradigm clash is occurring within behavior analysis. In the older paradigm, the molecular view, behavior consists of momentary or discrete responses that constitute instances of classes. Variation in response rate reflects variation in the strength or probability of the response class. The newer paradigm, the molar view, sees behavior as composed of activities that take up varying amounts of time. Whereas the molecular view takes response rate and choice to be “derived” measures and hence abstractions, the molar view takes response rate and choice to be concrete temporally extended behavioral allocations and regards momentary “responses” as abstractions. Research findings that point to variation in tempo, asymmetry in concurrent performance, and paradoxical resistance to change are readily interpretable when seen in the light of reinforcement and stimulus control of extended behavioral allocations or activities. Seen in the light of the ontological distinction between classes and individuals, extended behavioral allocations, like species in evolutionary taxonomy, constitute individuals, entities that change without changing their identity. Seeing allocations as individuals implies that less extended activities constitute parts of larger wholes rather than instances of classes. Both laboratory research and everyday behavior are explained plausibly in the light of concrete extended activities and their nesting. The molecular view, because it requires discrete responses and contiguous events, relies on hypothetical stimuli and consequences to account for the same phenomena. One may prefer the molar view on grounds of elegance, integrative power, and plausibility.

Key words: resistance to change, individual, class, concrete/abstract, molar, molecular, atomism

No man is an *Iland*, intire of it selfe; every man is a peece of the *Continent*, a part of the *maine*; if a Clod bee washed away by the *Sea*, *Europe* is the lesse . . . any mans *death* diminishes *me*, because I am involved in *Mankinde*; And therefore never send to know for whom the *bell* tolls; It tolls for *thee*.

John Donne (1572–1631)

Every scientific paradigm includes both epistemological claims—claims about knowledge, such as what it is and how it is obtained—and ontological claims—claims as to what we are to know about (Kuhn, 1970). In paradigm clashes, ontological claims often matter most. In the Ptolemaic view of the universe, the planets, like other heavenly bodies, revolve around the earth. Their irregular movements in the sky were explained with the use of epicycles, circles within the circular orbits around the earth. In the modern view, the sun, moon, and planets constitute a solar system. The concept of epicycle makes sense in one paradigm but is absent from the other. The concept of solar system exists in the oth-

er paradigm but is absent from the first. Neither concept is wrong. Each makes sense within one paradigm but is nonsense in the other. That is why, in contrast to theoretical disputes, paradigm clashes cannot be settled by data. Any particular set of data may be meaningful to one paradigm and meaningless to another or may have different interpretations according to different paradigms. The interpretations will be “incommensurate”—that is, each will make sense only within its paradigm (Kuhn, 1970).

The purpose of this paper is to describe and support a paradigm that has developed within behavior analysis over about the last 30 years. I will call it the molar view, because *molar* carries the connotation of aggregation or extendedness, and the molar view is based on the concept of aggregated and extended patterns of behavior. Its roots may be traced back to the 1960s, but it became clearly visible in the 1970s (e.g., Baum, 1973; Rachlin, 1976), and it was articulated explicitly in the 1980s and 1990s (e.g., Baum, 1997; Chiesa, 1994; Lee, 1983; Rachlin, 1994, 2000). Like the heliocentric view of the solar system, the molar behavior-analytic view clashes with an older paradigm (Baum, 2001; Dinsmoor, 2001; Hineline, 2001), which I will call the molec-

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ular view, because it is based on an atomism of discrete events at moments in time. I will focus on the contrasting ontological claims made by the molar and molecular views, even though they also clash on epistemological grounds (e.g., the uses of cumulative records vs. digital counters), because the ontological clash, though more fundamental, is less obvious.

THE MOLECULAR VIEW

In the 19th century, many psychologists sought to put psychology on a sound scientific basis by focusing on the association of ideas, sensations, and movements. These units of consciousness were conceived of as discrete events that could be "hooked" together or associated according to certain principles. Chief among these principles was the law of contiguity, which stated that two events that occurred close together in time (i.e., in temporal contiguity) would tend to recur together. In particular, if the idea of food happened to follow closely upon the idea of a musical tone, then when the idea of the tone recurred, the idea of the food would recur. This seemed a way to account for both the stream of consciousness and for the build-up of complex ideas from simpler ideas, as molecules are built up from atoms.

Although the association of ideas became less popular in the 20th century, the original atomism persisted in the concepts of stimulus and response. A stimulus was a discrete event in the environment, and a response was a discrete event in behavior. The principle of association by contiguity persisted in the concept of the conditional reflex.

In a classic paper, "The Generic Nature of the Concepts of Stimulus and Response," Skinner (1935/1961) attempted to create definitions of stimulus and response that would serve as the basis for a science of behavior. One can hardly overstate the importance of this paper to the development of behavior analysis. Skinner proposed a solution to the problem of particularity that plagues behavior analysis as it does any science: If each event (stimulus or response) is unique, how does one achieve the reproducibility required for scientific study? His answer was that a stimulus or a response was not a unitary event but was a class of unitary events. Although

any particular event might be described with great precision, the goal for defining a stimulus or response, as a class, was to specify the class's defining properties. The lever press, for example, would consist of the class of acts, all of which achieved the necessary movement of the lever. The nondefining properties could be ignored or could serve as the means for further differentiation. One would know if one's defining properties were correct by the consistency of one's results when the class is so defined—that is, in "smooth curves for secondary processes" (p. 366), what he was later to call functional relations. In this way, Skinner made possible a science of behavior—that is, behavior, as opposed to physiology or consciousness.

Skinner's stimulus and response, however, were classes of discrete events, the same sort of events as the previous century's ideas, situated at moments in time and explained by contiguity between events in time. A reflex for Skinner (1935/1961) was a correlation between two classes, meaning that when a member of the stimulus (as class) occurred, it would be followed by a member of the response (as class). Conditional reflexes were created by the repeated contiguity of members of the two classes. Later, he treated the law of effect in similar fashion: The response (as class) was strengthened by repeated contiguity between its members and the members of the reinforcer (as stimulus class).

Skinner (1938) equated response strength to probability. He proposed to measure probability as response rate. He saw response rate as an expression of response probability or strength, often writing as if this were the true dependent variable (Skinner, 1938, 1950, 1953/1961, 1957/1961). Response rate would be the outcome of probability acting moment to moment, as if at every moment a probability gate determined whether a response would occur just then or not. Changes in response rate were an outcome of changes in response strength, possibly acting locally, as in the fixed-interval scallop (Ferster & Skinner, 1957). Stimulus control occurred as a result of modulating response strength, as if in the presence of a discriminative stimulus the probability gate became more or less liberal in its moment-to-moment decisions.

A MOLAR VIEW

In 1969, Baum and Rachlin proposed a different view of response rate. We drew on T. F. Gilbert's (1958) suggestion that responses like lever presses and key pecks might occur in bouts at a constant rate, which he called the tempo of responding. Variation in response rate, in this molar view, would result from variation in the duration of bouts and the pauses between bouts (e.g., Shull, Gaylor, & Grimes, 2001). The time spent responding (T) at the tempo (k) would determine the number of responses (N): $N = kT$. If S is the duration of the sample (usually the session duration), then response rate (B) is given by

$$B = \frac{kT}{S}. \quad (1)$$

We suggested that behavior might be thought of as divided among activities that lasted for periods of time (i.e., bouts). Taking time as the universal scale of behavior, we proposed that the dependent variable be thought of as time spent responding ($T = N/k$) or proportion of time spent responding:

$$\frac{T}{S} = \frac{N}{kS}. \quad (2)$$

Accordingly, we wrote of choice as time allocation, the allocation of time among continuous activities, and we characterized the matching law as a matching of relative time spent in an activity to relative reinforcement obtained from that activity. The idea was extended to other changes in responding, such as behavioral contrast (White, 1978).

The elaboration of this idea is the paradigm that I am calling the molar view of behavior. Whereas the central ontological claim of the molecular view is that behavior consists of discrete responses, the central ontological claim of the molar view is that behavior consists of temporally extended patterns of action. I shall call these activities. Besides the concept of an activity, the molar view is based also on the concept of nesting, the idea that every activity (e.g., playing baseball) is composed of parts (batting) that are themselves activities. I shall focus first on activities and discuss nesting later.

Historically, the notion of reproducible discrete events, whether ideas or responses, al-

lowed a scientific approach to the subject matter. The concept of discrete response allowed quantification. Skinner's (1938) preparation, based as it was on the reflex, encouraged researchers to think of the response as momentary, as an event without duration. Skinner even set out one of his requirements for a response to study that it should be brief and easily repeated, because these properties would allow rate to vary over a wide range. A concept like the delay-of-reinforcement gradient depends on the idea that the response occurs at a certain point in time from which delay is measured. The concept of contiguity itself depends on the idea that two discrete events (e.g., response and reinforcer) mark the beginning and end of such a delay, the duration of which, for perfect contiguity, should be zero.

The notion of activity takes for granted the possibility of quantification, extending it beyond discrete responses and contiguity. The key difference lies in the recognition that activities take up time. In an earlier paper, I argued that the reinforcement relation might be thought of as a correlation (Baum, 1973). In the molar view, an activity like lever pressing, extending in time, is seen as *accompanied* by the reinforcers it produces. Many reinforcers may be involved, and consequences, being extended like activities, often consist of changes in reinforcer rate or changes in reinforcer magnitude. The idea that reinforcers accompany an activity might be misinterpreted to mean that delay is irrelevant, a claim that apparently would be easy to refute by experimentation. As in other paradigm clashes, however, in the molecular-molar clash the phenomena observed are simply seen in different terms. A procedure that arranges food delivery to immediately follow depressions of a lever arranges a strong correlation between lever pressing and rate of food delivery. A procedure that arranges food deliveries to follow responses at some delay arranges a lesser correlation, because the food deliveries may fail to accompany the activity. To effect changes in behavior, strong correlations work best; to maintain activities already occurring frequently, weak correlations may suffice (Baum, 1973).

The point might seem trivial, until we turn to other types of activity. Had Skinner chosen to study wheel running instead of lever press-

ing, his situation would have been different. Experimenters often measure wheel running in revolutions or quarter-revolutions, but these are artifices aimed at creating discrete responses where none are apparent. Premack (1965, 1971) instead proposed time as the measure. If we turn this reasoning onto activities like lever pressing, we see that discrete responses like lever presses are an outcome of instrumentation. "Responses" are momentary events (usually switch closures) contrived by the apparatus (e.g., lever or key). Their momentary character is only an artifact of the use of electrical switches. As a thermometer, whether stuck into a bowl of ice cream or a pile of cow manure, indicates only the temperature, regardless of the stuff it is stuck into, so a lever, when stuck into the activity of a rat, indicates only rate of switch closure, regardless of what sort of activity it is stuck into.

When I was a graduate student, laboratory practice dictated that one attach a lever or key to a pulse former, a device that would generate a uniform pulse on each operation of the lever or key. Laboratory lore claimed this was essential to keep the subjects from holding the switch. I tested this claim by omitting the pulse formers in an experiment on concurrent schedules (Baum, 1976). I measured both number of lever presses (switch operations) and time that the lever was depressed. The measures turned out to be equivalent, because the activity continued to result in jiggling of the lever, producing many switch operations. Even though the duration of the operations varied, the average was consistent enough that time and number of presses could be interchanged, as in Equation 2. Just as a rat's jiggling of a lever operates it at certain points in the jiggling, a pecking key operates only at a certain point in the movement of a pigeon's head. When Pear (1985) arranged a system for keeping continuous track of the position of a pigeon's head, key pecking appeared as cyclic motion, a wave form.

Two simple arguments might persuade one to think about behavior in terms of activities rather than discrete responses: (a) Momentary events are abstractions and (b) reinforcement operates by selection. The first, that momentary events cannot be observed, but only inferred, was argued in an earlier paper

(Baum, 1997). I shall recapitulate briefly. Suppose I show you a snapshot of a rat with its paw on a lever, and I ask you, "Is the rat pressing the lever?" You will have to reply, "I don't know. I have to see what comes next." You won't know until you see the whole (extended) lever press. In other words, you would never be able to tell from a momentary picture of the behavior what behavior was occurring at that moment. Only after the whole pattern unfolded would you be able to look back and infer that at that moment the rat was pressing the lever. The momentary response is never observable at the moment. It is always inferred afterwards. Like instantaneous velocity in physics, instantaneous behavior cannot be measured at the moment it is supposed to have occurred but must be inferred from a more extended pattern. That is why it might fairly be called an abstraction. That is why one may argue that it is impossible to reinforce a momentary response; one can only reinforce some activity with some duration.

The second argument is that reinforcement consists of selection. Possibly Ashby (1954) was the first to recognize the parallel between reinforcement and natural selection. Campbell (1956) spelled out the idea that reinforcement is a type of selection, and R. M. Gilbert (1970) and Staddon and Simmelhag (1971) elaborated it further. Skinner (1981) himself proposed it eventually. The essential point is that behavior varies as do genotypes within a population of organisms. As differential reproductive success increases some genotypes while decreasing others, so differential reinforcement increases some behavioral variants while decreasing others. This parallel, however, requires competition among variants, in the sense that the increase of one variant necessitates the decrease of others. With genotypes, this occurs because the size of the population tends to remain constant at the carrying capacity of the environment (i.e., the number of organisms that the resources of the environment can maintain). For behavior, the competition requires that the total of behavior in any period of time should, like the carrying capacity, remain constant. In other words, it requires that behavior take up time, and presumably that all the behavior that occurs in a time period take up all the time. Just as the limit to a biological

population necessitates that if longer necked giraffes increase in frequency then shorter necked giraffes must decrease in frequency, so the temporal limit to behavior necessitates that if pecks at the left key increase in frequency then pecks at the right key must decrease in frequency. At the least, the idea that reinforcement is a kind of selection requires that discrete responses must have duration. Add to that the possibility that the so-called responses may vary in duration, and you have granted that behavior consists of activities. The so-called response becomes indistinguishable from a bout of an activity.

Someone wedded to the molecular view might reply in a number of different ways. One might reject the analogy to natural selection altogether and stick with momentary responses. One might insist that in any time period greater and lesser amounts of behavior may occur. The molarist might reply that sacrificing the elegance of selection is a high cost to pay for the sake of keeping to momentary responses.

STRENGTH VERSUS ALLOCATION

The difference between the molar and molecular views may be seen in their different guiding metaphors. Whereas the molecular view relies on the idea of strength, the molar view relies on the idea of allocation. These different ideas depend on the different ontological claims of the two paradigms.

In the molecular view, reinforcers strengthen behavior. They do this by following immediately upon or soon after a bit of behavior, a response. The underlying assumption of a central role for contiguity in time entails the ontological claims of the molecular view, because contiguity exists at or around a certain moment in time. For two events to be contiguous, to occur close to the same moment, they must either be momentary or have distinct beginnings and ends. For a response to be followed immediately by a reinforcer, the response and the reinforcer must be discrete events. Thus, the contiguity-based notion of reinforcement espoused by the molecular view entails the ontological claim that behavior consists of discrete events.

Strength cannot attach to a single instance of a discrete unit, because each of those is

unique. Therefore, in the molecular view, strength attaches to the class and is inferred from the number of members of the class that occur in any given time period (i.e., from the calculated rate). A rat may press a lever 30 times per minute or twice per minute. I may drive to work seven times per week or once per week. A reinforcer may follow each occurrence of a discrete unit, but only some occurrences need be followed by reinforcers for the rate of occurrence of members of the class to be maintained—that is, reinforcement may be intermittent. The more often members of the class are reinforced, the greater the strength of the class.

In contrast, the guiding metaphor of the molar view is allocation. If the molecular view likens behavior to picking numbers out of a hat, the molar view likens behavior to cutting up a pie. Choice is time allocation (Baum & Rachlin, 1969). All behavior entails choice. All behavior entails time allocation. To behave is to allocate time among a set of activities. Such an allocation is a behavioral pattern. If a pigeon spends 60% of its time pecking at one response key, 30% of its time pecking at another, and 10% of its time in other, unmeasured activities, that is the pattern of its behavior while in the experiment. If a person spends 47% of his or her recreational time watching television, 40% reading, 10% walking, and 3% going to movies, that is a pattern of recreational behavior. Such patterns or allocations are necessarily extended in time.

Because every activity itself is composed of other activities—that is, because every activity is a whole constituted of parts—every activity itself contains an allocation of behavior. In this sense we may say that every activity *is* a behavioral allocation. The pigeon's allocation in the experiment may be called its experimental activity, and the allocation of recreational time may be called the person's recreational activity. We shall discuss this further when we take up the concept of nesting.

In the molar view, the appearance that behavior might be composed of discrete units arises because activities often occur in episodes or bouts. Task completion provides many examples: completion of a fixed-ratio run, of a house, of writing a paper, of reading a book. In the laboratory, the training of response chains originated to try to model such

extended units. In the molecular view, the sequence is thought to terminate at least some of the time with a reinforcer and to be held together with conditional reinforcers along the way to ultimate reinforcement. In the molar view, an activity like building a house entails a pattern of activities such as pouring the foundation, framing the structure, insulating, putting in windows and doors, and finishing the interior. House construction seems like a unit only because it is labeled as such, as one may call an episode of napping a nap or a bout of walking a walk. To a building contractor, construction of one house would seem more like an episode of building than a discrete unit. Against the molecular view, one might argue that behavioral chains sometimes bear little resemblance to extended behavior in the real world. Is it plausible to treat obtaining a bachelor's degree as a behavioral chain? Except for repetitive sequences like those of the assembly line, real-life sequences like building a house or baking a cake rarely follow a rigid order. Even the fixed-order chain of the laboratory (e.g., chain fixed interval fixed ratio) may be seen as a sequence of activities (fixed-interval activity, then fixed-ratio activity), and if some activities are maintained better than others, that is a matter to be studied. Completion of any task may be seen as an episode of an activity. Even activities that usually end in a certain way, such as search, last for varied durations; sooner or later the forager encounters prey, sooner or later one finds a parking space.

In particular, the molar view holds that the so-called response is an episode of an activity. Grant that pecks and presses take up time and that the time taken up by each cycle of activity—of body motion back and forth or up and down—takes up about the same amount of time (Baum, 1976; Pear, 1985), and then Equation 2 illustrates how switch operations (N) are convertible to time and how that time may be considered relative to the total (T). In other words, rate of pecking or pressing is equivalent to an allocation—relative time spent pecking or pressing. Even if counting responses is convenient, from the molar viewpoint a response rate is a relative time in the activity.

In the molar view, discrete behavioral units are not only illusory but often are simply impossible. As Baum and Rachlin (1969) argued

before, many activities lack any natural unit. What is the discrete unit of watching television, reading, sleeping, or driving a car? Applied behavior analysts recognize this when they set goals such as increasing time on task. Even in the laboratory, activities like wheel running and lever holding lack any nonarbitrary unit. Such activities, for which the molecular view must invent "responses," readily lend themselves to the idea of allocation.

THREE EXAMPLES OF MOLAR EXPLANATION

Although the conflict between two paradigms cannot be resolved by data, the power of a paradigm may be seen in its ability to interpret various phenomena of the laboratory. Three examples of the power of the molar view appear in its ability to treat (a) variation in tempo, (b) asymmetrical concurrent performances, and (c) resistance to change.

Variation in Tempo

Herrnstein's (1970, 1974) formulation of the matching law relied on response rate. He expressed it in the form

$$\frac{B_1}{\sum_{i=1}^n B_i} = \frac{r_1}{\sum_{i=1}^n r_i}, \quad (3)$$

which states that the relative response rate of any of n alternative responses matches the relative reinforcement obtained from those n alternative responses. Herrnstein (1970) further supposed that the sum total of behavior (the denominator on the left side of Equation 3) was a constant. On this assumption, Equation 3 is rewritten as

$$B_1 = k \frac{r_1}{r_1 + r_O}, \quad (4)$$

where r_O represents all reinforcement obtained from alternatives other than Alternative 1, and k represents the sum total of behavior expressed in the response units of B_1 .

In keeping with the notion of time allocation that Baum and Rachlin (1969) put forward, however, the constant k in Equation 4 may be reinterpreted as the tempo of the activity defining B_1 . It equals the response rate that would occur if all behavior were allocated to Alternative 1—that is, the response rate

if all the time were spent in Activity 1, sometimes called the asymptotic response rate. Substituting Equation 1 into Equation 4 allows one to rewrite Equation 4 to have proportion of time spent in Activity 1 matching proportion of reinforcement obtained from Activity 1.

One seeming challenge to Equation 4 arose from research by McDowell and associates (e.g., Dallery, McDowell, & Lancaster, 2000) that cast doubt on Herrnstein's assumption of constancy of k . They found that several operations, such as varying deprivation or reinforcer magnitude, result in different values of k when the response (of B_1) remains ostensibly the same. McDowell offered equations that predicted variation in asymptotic response rate, but at the cost of assuming discrete responses of invariant duration (e.g., McDowell, 1987). How might one explain variation in k while retaining the molar view?

One may interpret McDowell's findings as showing that the operations that vary k affect the tempo of responding, perhaps by affecting response topography. If k increases with increasing magnitude of reinforcement, that might be because the increased magnitude results in more vigorous responding, which results in less time per response. The higher tempo of the activity would result in more switch closures counted in the same amount of time. Thus the observation of varying k is readily accommodated by the molar view.

Asymmetrical Concurrent Performances

Another challenge to the matching law is the observation that behavior at two choice alternatives may differ qualitatively. The two-alternative version, expressed as

$$\frac{B_1}{B_2} = \frac{r_1}{r_2}, \quad (5)$$

may be thought of as derived by taking the ratio of Equation 3 to the similar equation written for Alternative 2. Such a derivation would be justified only if k were equal for the two alternatives. Suppose that the topography of the two responses differed, resulting in a difference in tempo (k). For example, suppose that one alternative was reinforced according to a variable-interval (VI) schedule and the other was reinforced according to a variable-ratio (VR) schedule (e.g., Baum &

Aparicio, 1999; Herrnstein & Heyman, 1979). If the tempo on the VR alternative were higher, the same amount of time spent at that alternative would result in more responses counted (i.e., more switch operations) there than if that time were spent at the VI alternative. Relative "responses" would deviate from matching.

The generalized matching law has been used to estimate such deviations from matching:

$$\frac{B_1}{B_2} = b \left(\frac{r_1}{r_2} \right)^s, \quad (6)$$

where b is a proportionate bias that is independent of the rates of reinforcement, r_1 and r_2 , and s is the sensitivity to variation in the ratio of reinforcement. If b and s both equal 1.0, the strict matching of Equation 5 occurs. When deviations from strict matching occur, they are usually estimated as values of b and s different from 1.0. If the tempos of B_1 and B_2 differed, one would expect a value of b different from 1.0, favoring the VR (e.g., Baum & Aparicio, 1999; Herrnstein & Heyman, 1979).

A stronger challenge to the matching law arises from the observation that a difference in topography or tempo may affect s (Baum, Schwendiman, & Bell, 1999). Equation 6 is usually fitted to behavior and reinforcer ratios in its logarithmic form,

$$\log \frac{B_1}{B_2} = s \log \frac{r_1}{r_2} + \log b, \quad (7)$$

because this form is symmetrical around the indifference point (behavior and reinforcer ratios both equal to 1.0) and because, being linear, it is easier to fit. The equation is fitted to behavior ratios determined for several reinforcer ratios to both sides of equality (i.e., sometimes making Alternative 1 richer, sometimes making Alternative 2 richer) on the assumption that parameters s and b remain independent of variation in the reinforcer ratio. Baum et al. found that when pigeons were exposed to pairs of concurrent VI schedules long enough for performance to remain stable over a substantial sample, the behavior ratios deviated systematically from Equation 7. On closer examination, a simple pattern of behavior appeared: Responding occurred almost exclusively on the rich alternative, in-

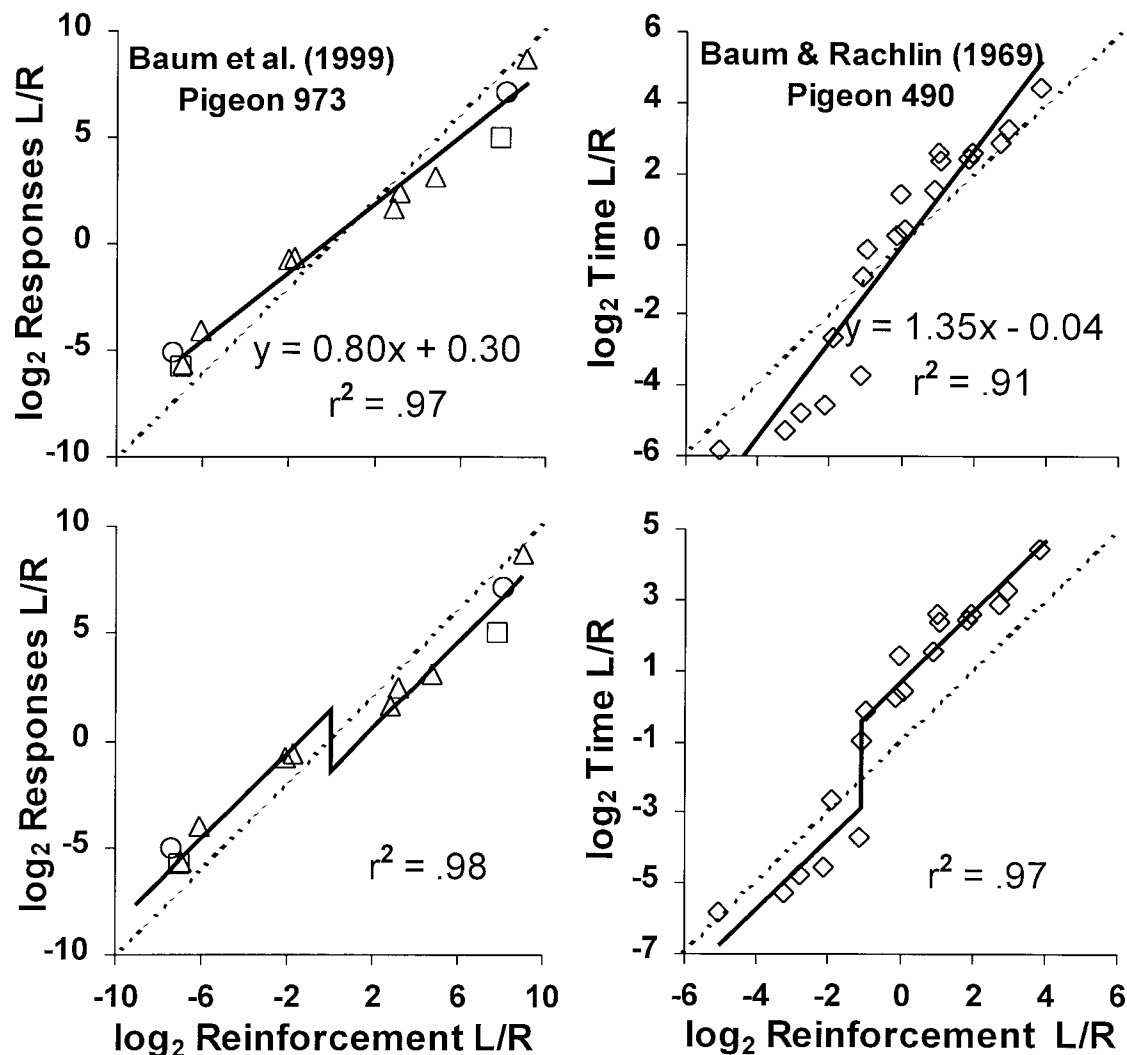


Fig. 1. Apparent deviations from matching explained by the fix-and-sample pattern. Left: The top graph shows apparent undermatching. Close examination reveals systematic deviation from the fitted line (the generalized matching law). The bottom graph shows the same data fitted with the two lines predicted by fix and sample. Right: an instance of apparent overmatching, with systematic deviation from the generalized matching law. The bottom graph shows the data fitted with the two lines predicted by fix and sample, eliminating the systematic deviation.

interrupted only by brief visits to the lean alternative. This pattern, which we called "fix and sample," predicted two lines, each with slope s equal to 1.0 but with different bias b , depending on whether Alternative 1 or Alternative 2 was the lean alternative (Houston & McNamara, 1981). We found that the two-line model, with the same number of parameters as the one-line model, fitted the data better and with no systematic deviations.

Figure 1 illustrates the finding. The two left graphs show the behavior ratios from Pigeon

973, fitted with one line (top) and with two lines (bottom). A casual look at the top graph would lead one to conclude that the results were typical of such experiments: a good fit to Equation 7 with a moderate amount of undermatching ($s = 0.8$). Closer inspection reveals that, going from left to right, the data points first lie above the line, then below the line, then above again, and then below again. Not only is the two-line fit better, but also the variation in choice appears to conform closely to the assumed slopes of 1.0. Indeed, the

undermatching shown in the top graph is explained by the inappropriate fitting of one line to data better described by two.

The two right graphs in Figure 1 demonstrate a similar explanation for an example of apparent overmatching. They show behavior ratios from Pigeon 490 in the Baum–Rachlin (1969) experiment, fitted with one line and with two. Again the two-line fit (bottom) shows less systematic deviation, again the slopes of 1.0 seem appropriate, and again the apparent deviation of slope s from 1.0 may be explained as the result of inappropriate fitting of one line to data better described by two.

Although the two-line fits in Figure 1 both show biases that explain the deviations of s from 1.0, these biases differ from the bias b in Equations 6 and 7. Whereas the usual bias is assumed to be independent of reinforcer ratio, the biases in the two-line model depend on the reinforcer ratio, because they depend on which is the leaner alternative. In the undermatching example, the bias favored whichever was the lean alternative. In the overmatching example, the bias favored whichever was the rich alternative. The overmatching example shows standard position bias too; that is why the vertical crossover occurs at a reinforcer ratio less than 1.0.

The results shown in Figure 1 support the idea that behavior at the rich alternative and behavior at the lean alternative constitute different activities that, in turn, comprise parts of a more extended pattern (i.e., the fix-and-sample activity) involving both alternatives. Behavior at the rich alternative consists of staying there—fixing—whereas behavior at the lean alternative consists of brief visiting—sampling. In the undermatching example, the pigeons pecked at two keys, but visits to the lean key nearly always consisted of single isolated pecks. To explain the apparent bias in favor of the lean alternative, one need only assume that less time was spent per peck at that key. For example, a pigeon stationed in front of the rich key would “travel” to the lean key by stretching its neck toward the key, and in that position, make a brief exploratory peck. Measured as time spent, a number of pecks at the lean key would represent less time than the same number of pecks at the rich key, and counting them equally would overestimate the time spent at the lean alter-

native. In other words, if the subscripts in Equation 7 were reinterpreted to mean rich and lean, rather than left and right, then the bias would differ from 1.0 only because the time per peck differed, just as the earlier discussion suggested for concurrent VI VR schedules.

In the overmatching example, Baum and Rachlin (1969) measured only time spent on two sides of a chamber; there were no response keys. We observed informally that the pigeons would station themselves near the middle of the chamber and move rapidly back and forth. Whereas behavior on the rich side consisted of standing or dancing, a visit to the lean side consisted of stepping over there, waiting out the signaled changeover delay (COD), and then either running to the feeder on the lean side or immediately hopping back again to the rich side. Under such circumstances, the visits to the lean side constituted brief episodes of an activity (i.e., sampling) different from that at the rich side (fixing). One need only assume that our procedure underestimated the time spent per visit to the lean side to explain the apparent biases in the lower right graph in Figure 1. In particular, we excluded time spent during the COD from our calculations, on the ground that it was signaled timeout from the experiment. Had we included that time, we would have had to decide how to allocate it between the two sides. Owing to premature changeovers to the lean side, most of the changeover time was probably spent on the lean side. Limitations of our electromechanical equipment prevented us from solving this problem.

The important point made by Figure 1, however, is that such instances of undermatching and overmatching may be readily explained by adopting the molar view, because it allows choice between the rich and lean alternatives to be seen as time allocation between two different activities. The molecular view presumably would explain Figure 1 as the aggregation of many discrete responses made at the two alternatives, combined with assumptions about the reinforcement of switching and delay gradients. A molarist might judge the account logically correct, but would regard it as implausible and inelegant, illustrating once again that a paradigm clash

is resolved by such considerations rather than by data (Kuhn, 1970).

Activities, Stimulus Control, and Resistance to Change

A seeming challenge for the molar view comes from research and theory about behavioral momentum, a recent reexpression of the notion of response strength (Nevin, 1974, 1992; Nevin & Grace, 2000). The experiments show that persistence of responding (resistance to change) depends on prior rate of reinforcement. The molar interpretation of the results, which eschews response strength, stems from a molar view of reinforcement and stimulus control.

In an earlier paper (Baum, 1973), I argued that, just as behavior is extended, so too are consequences extended. As response rate is real (i.e., to be known about), so rate of reinforcement and rate of punishment are real. The molar analogue to contiguity is correlation—that is, correlation between extended activities and extended consequences. If I forget to add baking powder when I'm making a cake, the result is disappointing, but my cake baking generally pays off well and is maintained by its high rate of mainly good consequences. In the molar view, reinforcement is like starting and stoking a fire. Special materials and care get the fire going, and throwing on fuel every now and then keeps the fire going.

McDowell's experiments on variation in k (e.g., Dallery et al., 2000) and experiments on asymmetrical concurrent performances support the idea that behavior consists of extended allocations or activities. Reinforcement and punishment may change the time spent in an activity (i.e., allocation), but also may change the allocation among the parts and even the parts themselves. This latter kind might be called change in topography, referring roughly to the way an activity is done. Whatever the change, the molar view attributes it to differential extended consequences.

Once we move away from the atomism of discrete responses, we should expect that the way we talk about reinforcement and stimulus control will change too, even if only in subtle ways. In the molecular view, for example, "continuous" reinforcement is often contrasted with "intermittent" reinforcement.

One may question whether the notions of intermittent and continuous reinforcement have any meaning in relation to extended activities. In the molar view, reinforcers coincide with various parts of the activity in various forms. What matters is the aggregate of consequences that the activity (allocation) produces relative to other activities (allocations) over time. In the simplified environment of the laboratory, concurrent schedules arrange that a pattern of choice (an allocation) produces a rate of reinforcement (Baum, 1981). As with choice patterns of self-control, in which impulsive behavior is immediately reinforced and self-control pays off better only in the long run, even though the more extended choice pattern would produce more reinforcers in the long run, local reinforcement contingencies may prevent the choice pattern (allocation) from evolving toward the maximum possible (Rachlin, 1995, 2000; Vaughan & Miller, 1984). An experiment by Heyman and Tanz (1995), however, showed that providing signals allowed changes in reinforcer rate to reinforce changes in choice pattern (allocation). They arranged that when pigeons' choice over a sample of responses deviated toward a more extreme allocation than would be expected from the matching law (Equation 5), relative reinforcement would remain unchanged, but that the overall reinforcer rate would increase and a light would come on. They found that deviations from matching were reinforced by the changes in overall reinforcer rate.

The molar concept of reinforcement also implies a molar concept of stimulus control. In the experiment by Heyman and Tanz (1995), the light signaled a relation between an extended pattern (an allocation) and an increase in reinforcer rate. In the molecular view, a discriminative stimulus signals that some responses may be intermittently reinforced, and its presence increases the probability of the response. In the molar view, a discriminative stimulus signals more frequent reinforcement of one activity or allocation than another, and its presence increases the time spent in that activity. Reinforcers that occur in the presence of the stimulus plus the presence of the activity or allocation increase the control of the stimulus over that activity or allocation.

In the molar view, a response rate, whether

measured in experiments in which the activities consist of repetitive motions like key pecks or lever presses (e.g., White, 1985) or used to measure general activity (Buzzard & Hake, 1984), is equivalent to an allocation, a pattern of behavior, an activity. We have seen that experiments on variation in k and asymmetrical concurrent performances may be interpreted as changes in response rate resulting from changes in extended patterns of responding. Heyman and Tanz's (1995) experiment embodies the molar idea of stimulus control, in which control over extended patterns of responding entails control over response rate and choice. If extended patterns of behavior (activities or allocations) may be reinforced and controlled by discriminative stimuli, then we should expect that response rates are both reinforceable and subject to stimulus control.

We may apply these expanded notions of reinforcement and stimulus control to experiments on behavioral momentum and resistance to change (Nevin, 1974, 1992; Nevin & Grace, 2000). In a typical experiment, pigeons are exposed to a multiple schedule composed of two components, each consisting of a VI schedule of food reinforcement for pecking at a response key. One VI is richer than the other and thus maintains a higher rate of key pecking. Once the two rates of key pecking have stabilized, a variety of different operations may be used to disrupt the responding; the usual ones are prefeeding, food presentations during timeout periods between components, and extinction. The typical result is that response rate decreases in both components, but by a larger proportion in the component with fewer reinforcers. For prefeeding and food presentations between components, the decreases in response rate might be interpreted as the result of a decrease in magnitude of programmed (VI) reinforcement relative to background reinforcement. In terms of Equation 4, these operations would decrease rate of pecking by increasing r_0 . How Equation 4 might account for the difference in rate of extinction is less clear, but one might suppose that higher rates of key pecking, once established, tend to persist longer in the absence of reinforcement. Nevin, Tota, Torquato, and Shull (1990) reported an experiment, however, that undermined such seemingly straightfor-

ward explanations. Pigeons were exposed, as usual, to a multiple schedule, one in which the same VI schedule occurred in both components. In one component, however, it was the only schedule present, whereas in the other component, a second schedule reinforcing pecks on a second key (Experiment 2) or delivering food independently of behavior (Experiment 1) was paired with the constant schedule. Although the overall rate of reinforcement was lower in the single-VI component, the response rate there was higher than the response rate on the same key in the component with the concurrent VI (as would be expected; Rachlin & Baum, 1972). The crucial result was that, comparing the response rates on the constant-schedule key during extinction, the lower response rate decreased more slowly than the higher response rate.

Nevin (1992) interpreted this result and the earlier experiments to mean that reinforcement builds behavioral momentum: The more reinforcement, the more momentum; the more momentum, the less the response is susceptible to disruption. To maintain this theory, however, he had to distinguish between what he called operant and respondent aspects of the components. The difficulty was that pecks at the constant-VI key were reinforced at the same rate in both components; the extra reinforcers that made the difference in resistance to change were associated with the second key or some other behavior, and how reinforcement of other behavior could increase a response's momentum was unclear. Nevin concluded that, because the overall reinforcer rate was higher in the two-VI component, the momentum of all behavior in a component must depend on all the reinforcers in that component. The association of reinforcers for other behavior with the component's stimulus constituted a respondent or Pavlovian aspect to determining momentum.

The ideas of reinforcement and stimulus control of extended patterns of behavior (allocations) open the way to a different interpretation of experiments on resistance to change. In a multiple schedule, we may suppose that if the contingencies of reinforcement differ from component to component, they will generate different allocations of behavior in the presence of the different dis-

criminative stimuli. All the reinforcers in a component serve to reinforce the allocation occurring there, and the stimulus enjoins that allocation. The more reinforcement, the more the stimulus enjoins the allocation. In a multiple schedule with two different VI schedules in two components, the higher reinforcer rate will be associated with the allocation that generates (i.e., is equivalent to) the higher response rate, stimulus control will be stronger over that allocation, and that stimulus will sustain that allocation longer as it disintegrates (i.e., transforms into some other allocation including little or no pecking) during extinction. As the experiments show, the higher rate allocation will take longer to disintegrate than the lower rate allocation. In Nevin et al.'s (1990) crucial experiment, different allocations occur in the one-VI component and in the two-VI component. The allocation in the one-VI component entails a higher response rate on the constant-VI key, but that allocation is less reinforced. The allocation in the two-VI component entails responding on both keys and is more reinforced. Because stimulus control is stronger over the two-VI allocation, that one disintegrates more slowly during extinction. Hence the response rate on the constant-VI key falls more slowly in the two-VI component.

Although this explanation of variation in resistance to change bears some similarity to Nevin's explanation, it has advantages. First, it is arguably simpler. It requires no appeal to separate operant and respondent aspects, because it invokes only the idea that stimulus control depends on rate of reinforcement. Second, it requires only an expansion of the concepts of stimulus control and reinforcement to apply to extended patterns of behavior, instead of the introduction of new concepts, such as behavioral momentum and mass (Nevin & Grace, 2000). These concepts, borrowed by analogy from Newtonian mechanics, seem particularly unlikely to explain the dynamics of behavior, because mechanics offers only nonhistorical immediate causes (Aristotle's efficient causes; Rachlin, 1995). In the molar view, reinforcement is a process of selection, resembling natural selection—an entirely different sort of causation and fundamentally historical (Baum & Heath, 1992; Baum & Mitchell, 2000; Skinner, 1981).

IDEAL RESPONSE CLASSES VERSUS CONCRETE BEHAVIORAL PATTERNS

The concept of behavioral momentum, like the concept of response strength, flows from the molecular, atomistic view of behavior. Momentum, like strength, is considered the possession of a class, the members of which are momentary responses. Skinner's (1935/1961, 1938) operant, for example, was a class with discrete responses as members, and when its strength was high its members occurred at a high rate. His ill-fated idea of the reflex reserve depended on just such a notion of strength, and Nevin's notion of momentum—the contemporary equivalent of the reflex reserve—similarly depends for its definition on the idea of response class. In the molecular view, one supposedly specifies the ideal properties required for membership in the class (e.g., a certain force, a certain extent, etc.). Any lever press or key peck that possesses the ideal properties may be recorded. To estimate response rate, one counts a number of instances and divides by the time interval during which they were counted. An increase or decrease in response rate reflects an increase or decrease in strength or momentum of the class. The more the members of the class are reinforced, the more is the class's strength. That response rates on interval schedules fall short of those on ratio schedules, for example, is explained by the differential reinforcement of long inter-response times (IRTs) in interval schedules, the IRT being considered another property of the response or instance (Ferster & Skinner, 1957; Morse, 1966). Reinforcement then selectively strengthens different response classes. The high rates on ratio schedules are attributed to the absence of differential reinforcement of IRTs. In this view, response rate always remains an abstraction, because the concrete particulars are the responses, the class instances.

In the molar view, an activity occupies more time or less time, depending on the conditions of reinforcement. No notion of strength or momentum enters the picture. When behavior is seen as composed of continuous activities or extended patterns (i.e., allocations), response rate is no longer an expression of strength or momentum. A re-

sponse rate, as an allocation, is seen as concrete.

Increases or decreases in rate of key pecking may or may not indicate increases or decreases in the time spent pecking. The examples of varying k (tempo), asymmetrical concurrent performances, and varying resistance to change show that at least two possibilities exist. First, response rate may increase or decrease because the mix of activities changes to include more or less time spent in the repetitive activity, as implied by Equation 4 (cf. Shull et al., 2001). Second, response rate may increase or decrease because the repetitive activity itself (its topography) changes. The difference in response rates between ratio and interval schedules arises because the schedules reinforce different patterns of responding—that is, different activities. Interval schedules differentially reinforce activities that result in lower rates of key operation, whereas ratio schedules differentially reinforce activities that result in high rates of key operation (Baum, 1981). Across the low range of reinforcer rates, as reinforcer rate increases across VI schedules (i.e., as the average interval gets shorter), response rate increases and levels off, as Equation 4 would predict, but when the VI schedule becomes brief enough, it begins to function like a ratio schedule, and response rate increases up to the same level as for a comparable VR (Baum, 1993). The increase across the low range of reinforcer rates represents an increase in time spent in low-tempo key pecking, whereas the increase across the high range of reinforcer rates represents an increase in time spent in high-tempo key pecking (Baum, 1981, 1993).

Class Versus Individual

This difference between the molecular and molar views—the difference between response strength and behavioral allocation—corresponds to the ontological distinction between class and individual (Ghiselin, 1997; Hull, 1988). The molecular view, as laid out by Skinner (1935/1961), relied on the notion of operant classes. A class is defined by specifying a list of properties or rules of membership (e.g., all actions that depress the lever). Classes are abstract in the sense that one can only talk about them, not point to them or measure them. Their abstract nature appears

also in the lack of any requirement that they have members or that such members exist (e.g., human beings who can leap over tall buildings in a single bound). Useful classes have members, which, unless they are other classes (a possibility we will ignore here), constitute concrete particulars—concrete in the sense that one can point to them or at least observe them, and particular in the sense that each is just one thing. So, although operant classes are abstract, responses (instances) would be considered concrete (Skinner, 1935/1961).

Besides being members of classes, concrete particulars are individuals (see Ghiselin, 1997, and Hull, 1988, for longer explanations). An individual is a cohesive whole that is situated in space and time—a historical entity. That is, an individual (e.g., B. F. Skinner) has a location, a beginning, and potentially an end. Individuals have no instances (e.g., B. F. Skinner is who he is and has no instances). Individuals cannot be defined except by ostension (i.e., by pointing; e.g., that is my cat there). Individuals have parts (left leg, right leg, liver, and heart), rather than instances. The quote from John Donne at the beginning expresses well the relation of part to whole; as a clod is part of Europe, so any man is a part of mankind. Classes cannot do anything; only individuals can do things (e.g., *cat* cannot walk into the room, whereas *my cat* can).

In particular, whereas individuals can change, classes cannot change. B. F. Skinner changed from boyhood to adulthood, but he was still the same individual, B. F. Skinner. A class remains fixed because it is defined by fixed properties or rules. If the properties or rules change, we only have a new class. The only change associated with a class is in the number of its instances. Were we to discover an individual able to leap tall buildings in a single bound, that class would no longer be empty. Mathematical sets cannot change even in this way, because adding or subtracting elements from a set creates a new set.

Any science that deals with change, whether phylogenetic change, developmental change, or behavioral change, requires entities that can change and yet retain their identity (e.g., *Homo sapiens*, my cat, or my diet), because only such entities provide historical continuity. In other words, because only in-

dividuals can change and yet maintain historical continuity, such a science must deal with individuals. Although individual usually means individual organism in everyday discourse, philosophers mean something more general. Organisms exemplify cohesive wholes, but so too do activities or allocations. Just as an organism is made up of a liver, kidneys, brain, and the like, functioning together to produce results in the environment, so too an utterance (e.g., "I need help with this problem") is made up of sounds that function together to produce results in the environment. The various parts of the whole are themselves individuals (e.g., the liver or the uttered word "help"); all individuals are composed of other individuals. This point will be important when we discuss the nesting of activities.

By way of example, we may compare the molecular and molar accounts of differential reinforcement ("shaping"). Skinner (1935/1961) recognized that reinforcement of a certain class of responses generates responses that may actually lie outside the reinforced class. He called this process *induction* (see also Segal, 1972). Induction is essential for shaping novel behavior, because the new induced responses may be reinforced. To do this, one defines a new class for reinforcement, one that excludes some of the old members. Reinforcement of this new class leads to induction of further new responses, which allows definition of another new class, and so on, until some target class is reached.

One challenge for this molecular account of shaping is that reinforcement may induce undesirable behavior, sometimes called adjunctive or interim behavior (Staddon & Simmelhag, 1971). The problem is that such behavior interferes with the process of shaping (Breland & Breland, 1961; Segal, 1972) and falls outside the reinforced classes. Consequently, the molecular view treats it as a separate type, distinct from operant behavior and with rules of its own.

The molar view of shaping instead incorporates induced behavior into the account. The process begins, not with a response class, but with an allocation of activities (an individual). Some activities (parts) are reinforced. The allocation changes, the parts reinforced change, and the allocation changes further. Induced activities may enter the allocation at

any stage; they become new parts. The end-point of the process (if any) will be a stable allocation maintained by stable reinforcement contingencies.

Although the idea that particular discrete responses are instances of a class remains common (e.g., in textbooks), the molecular view allows at least one other possibility. Glenn, Ellis, and Greenspoon (1992) proposed that the aggregate of particular occurrences be thought of as analogous to a population of organisms. As each individual organism is a part of the population, so each particular discrete unit is a part of a behavioral population, rather than an instance of a class. Thus, one could redefine an operant as a behavioral population, which would be an individual rather than a class. Response rate then would correspond to the size of the population. Such a population would constitute an individual, but different from an activity or allocation, because its parts would be discrete responses (Glenn & Field, 1994). Their proposal illustrates that the molecular view cannot be said to entail the concept of response class in the way that it can be said to entail discrete units.

During the 1960s and 1970s, Skinner's notion of the operant as a class came in for critical discussion (e.g., Schick, 1971; Segal, 1972; Staddon, 1973). The main problem was how to deal with the induction of new behavior. Catania (1973) proposed a solution that resembles the proposal by Glenn et al. (1992). He suggested distinguishing between the descriptive operant and the functional operant—that is, between the operant as specified by class properties and the operant as the pattern of behavior that actually results from reinforcement. Catania's suggestion overlooks, however, that the functional operant constitutes a different ontological kind, one that eludes definition by a list of properties. It overlooks that, in moving from descriptive operant to functional operant, one also moves from class to individual. The functional operant, which Catania represented by drawing frequency distributions, corresponds to a population of responses, but the responses no longer can be seen as instances of a class, because now they are parts of a whole—whatever unspecified responses occur after reinforcement. They could be seen (in the molar view) as parts of an extended behav-

ioral allocation, an individual. That allocation is both engendered by and maintained by the reinforcement it produces. Like Glenn et al., however, Catania based his idea on discrete responses. In their related discussion, Glenn et al. argued,

In the ontological sense, an operant is . . . an entity—a unit, an extant individual. . . . It is composed of a population of behavioral occurrences that are distributed over time, each occurrence having a unique spatiotemporal location. The operant can evolve (as only operants and species can but organisms and responses cannot). (p. 1333)

The main difference between this and the molar view is its implicit reliance on discrete responses (“occurrences”). If one added the point that the occurrences take up time, introducing an analogue to the carrying capacity (limited size of a biological population), and one added that the occurrences were bouts of extended activities, the concept of behavioral population would become almost the same as the concept of allocation. One further concept, implied by the analogy to biological evolution, is the idea that activities are nested, that every activity (allocation) is composed of parts that are other activities.

Species and Activities As Individuals

Another way to understand the concreteness of behavioral allocations, activities, and response rates is by comparison to evolutionary theory. Glenn et al. (1992) were drawing on Ghiselin’s (1981, 1997) argument that species are not classes but individuals. That is, the relation of an organism to its species is not the relation of instance to class, but the relation of part to whole. As before, the word *individual* here refers to an integrated entity that may change through time. As before, in contrast to a class, an individual is situated in time and space (i.e., has a beginning and end) and has parts but no instances (e.g., B. F. Skinner). An organism is an individual, of course, but, Ghiselin explains, so too is a species. A species is an individual composed of the organisms that make it up, in the same way as John Donne noted that every man is a part of mankind. All the individual birds in the Galapagos Islands that make up the species *Geospiza fortis* are parts of that whole. Selection may change a species through time,

particularly if the environment changes, but the species remains the same individual, just as a person who grows and ages remains the same individual. The existence of a species through time is referred to as its *lineage*. A lineage is an extended temporal entity in much the same way that a pattern of behavior is an extended temporal entity.

Ghiselin’s point was at first controversial among biologists, but gradually gained acceptance. Now, even its critics acknowledge that “Only a few biologists and (bio)philosophers have resisted [it]” (Mahner & Bunge, 1997, p. 254).

Like a species, an allocation of behavior—an activity—is an individual. It is an entity with a beginning and an end, integrated by its function; that is, by its effects in the environment. Just as taking away an organism’s leg changes its functioning, so taking away part of a behavioral pattern changes its environmental effects. Forget to add baking powder to a cake mix, and the result may be inedible. A particular cake baking, however, is part of a more extended allocation of baking or cooking, including both successful and unsuccessful attempts and all their various outcomes.

This illustrates another parallel between extended activities and species: their similar participation in larger individuals. Common ancestry unites species into more extended individuals at the level of genus. Genera unite into still larger individuals, and so on, right up to phylum and, finally, life (Ghiselin, 1997). Although individuals at these various taxonomic levels may be more or less extended, no matter how large or small they still are individuals. *Homo sapiens*, as a species in the genus *Homo*, is a part of the genus, just as the other species in that genus are parts of it. *Geospiza fortis* is one species of Darwin’s finches. It, *Geospiza scandens*, and several other species make up the genus *Geospiza*. In relation to the genus, the species are parts of a whole, not instances of a class.

NESTING OF ACTIVITIES

Activities, like species, are parts of more extended activities. Getting to work each day may be part of working each day. Working each day may be part of holding a job. Hold-

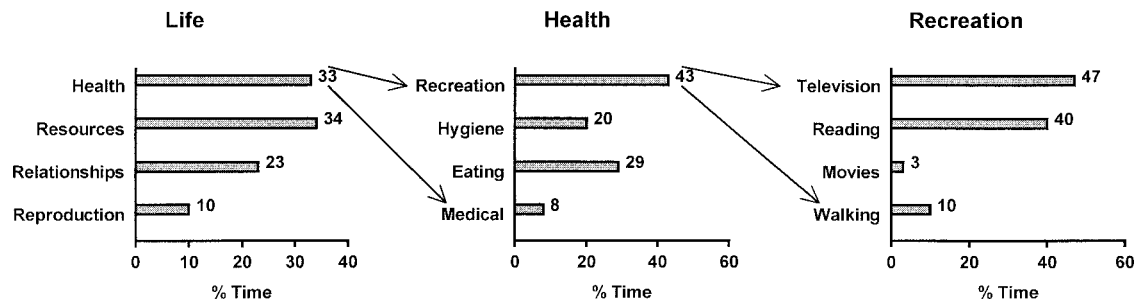


Fig. 2. One person's hypothetical activity patterns. Left: pattern of life activities, showing time divided among health and maintenance (i.e., personal satisfaction), gaining resources (e.g., job), relationships (e.g., friends), and reproduction (e.g., family). Middle: pattern of health and maintenance nested within the life activities, showing time divided among medical (e.g., visits to practitioners), eating, personal hygiene, and recreation. Right: pattern of recreation nested within health and maintenance, showing time divided among watching television, reading, movies, and walking (i.e., exercise). All of these patterns constitute individuals, because they change without changing their identity.

ing a job may be part of making a living. Making a living may be part of gaining resources. Gaining resources may end with retirement, and all such parts may make up a whole, which we could call a lifetime lived (Baum, 1995, 1997; Rachlin, 1994).

The converse holds, too: Activities and species are made up of parts consisting of less extended individuals. A species may be composed of several populations. A population may be composed of several demes. Demes, populations, and species all are composed of organisms, which are composed of organs, which are composed of cells, and so on. For the purposes of evolutionary theory, one stops at the smallest individual that may evolve—a deme, a population, or a species. An activity like getting to work may be composed of parts like starting the car, driving to the highway, driving on the highway, driving to the campus, hunting for a parking place, and walking to the office. Driving on the highway has parts like adjusting speed, switching lanes, scanning for police cars, and swearing at other drivers. And so on, for each part. Some least extended activity exists for the analysis of behavior, as it does for evolutionary theory, defined by its usefulness and, probably, by its likelihood of evolving. Highly practiced and stereotyped activities like shifting gears in a car change rarely; they attract little interest as targets of modification, whereas driving speed may change significantly and is a frequent target of attempts at modification (e.g., "speed kills").

The Molar View of Everyday Life

We may illustrate the conceptual power of the idea of nested activities with a hypothetical example. Liz is a married woman in her 40s, who lives in a city, works selling retirement plans for a mutual fund company, and has an 18-year-old son who still lives at home. As I suggested in earlier papers (Baum, 1995, 1997), her life may be divided into four basic activities: personal satisfaction (i.e., health and maintenance), job (i.e., gaining resources), relationships, and family (i.e., reproduction). The left graph in Figure 2 shows the pattern of these activities at this point in Liz's life. Leaving out the 9 hr she spends sleeping each night, we see that she spends about 35 hr (33%) per week in personal satisfaction, 36 hr (34%) in gaining resources, 24 hr (23%) in making and maintaining relationships, and 10 hr (10%) in family activities. The allocation was different 10 or 15 years earlier, when her son was young and she was caring for her husband's children from previous marriages. As an individual, the activity has changed and will change again over the course of Liz's life, but it will remain the same individual, the pattern of Liz's life. All four of the activities shown in the left graph may be analyzed in more detail and seen to be composed of other activities. For example, Liz's family activities consist of occasionally caring for her husband's grandchildren and primarily of caring for her son: feeding him, cleaning up after him, advising him, and in-

terfering in his life sufficiently to make him rebellious.

The middle graph in Figure 2 shows the time Liz spends in personal satisfaction decomposed into parts. She spends about 3 hr (8%) per week seeing medical practitioners, 10 hr (29%) eating, 7 hr (20%) in personal hygiene, and 15 hr (43%) in recreation. This allocation also is an individual, subject to change, and is nested within or incorporated into the more extended allocation of Liz's life activities. Each of the activities composing the activity of personal satisfaction also is an individual and is itself composed of individuals. The right graph in Figure 2 shows Liz's recreational activities broken into parts. She spends about 7 hr (47%) per week watching television, 6 hr (40%) reading, 0.5 hr (3%) watching movies, and 1.5 hr (10%) walking for exercise. This allocation of recreational activity constitutes an individual and is part of Liz's personal satisfaction and, because of that, is part of Liz's life activity. Each of the parts of Liz's recreational activities could be further decomposed into parts that also would be individuals (Baum, 1995, 1997).

In contrast, the molecular view invites one to view life as a time line of discrete events, one following another—a behavioral stream (e.g., Schoenfeld & Farmer, 1970). To the molarist, such a characterization, though possible, appears impoverished and to resemble little the way people actually talk about their lives (i.e., inelegant and low on external validity).

Figure 2 implies that one might go into any amount of detail about Liz's activities. Where should subdividing stop, and how does one define the parts? Answers would depend on the purpose of the analysis, whether it be therapeutic intervention, basic research, or something else. The issues involved are addressed most directly in the context of laboratory research.

Applications in the Laboratory

As a laboratory example, we may consider activities like key pecking and lever pressing. A pigeon's food peck, when examined in detail, constitutes an individual with parts: forward head motion, eye closing, opening of the beak, head withdrawal, closing of the beak, eye opening (Ploog & Zeigler, 1997; Smith, 1974). It is a stereotyped pattern that

researchers almost never seek to change, although other sorts of pecks, containing different parts, exist, such as water-reinforced pecks and exploratory pecks (Jenkins & Moore, 1973; Schwartz & Williams, 1972; Wolin, 1948/1968). A similar, though more varied, list of motions might be made for a rat's lever press. Key pecks or lever presses may be parts of key pecking or lever pressing reinforced, say, on a VI schedule. Key pecking or lever pressing on two different keys or levers may be parts of an allocation of behavior between two sources of reinforcement (Ploog & Zeigler, 1997). We usually measure the responding on one of the keys or levers as a response rate. We measure the allocation as choice or relative response rate.

In contrast, the molecular view sees choice or concurrent performance as consisting of occurrences of two responses, each at a certain rate. The response rates may be compared by calculating some relative measure (proportion or ratio) but such a measure is seen as only a summary or as "derived" (Catania, 1981; Herrnstein, 1961). At least one researcher has suggested that relative measures, as derived, should be viewed with suspicion and that response rate is the only true measure of behavior (Catania, 1981). The limitations of such a view become apparent when we consider a specific example.

Alsop and Elliffe (1988) exposed 6 pigeons to over 30 pairs of concurrent VI schedules, varying both relative and overall rate of reinforcement. I reanalyzed their data by grouping them according to five levels of reinforcer ratio (r): 0.12, 0.25, 1.0, 4.0, and 8.0. Within each group, the obtained reinforcer ratios varied a bit, but the variation from group to group was larger than the variation within a group (although to achieve this, five conditions with aberrant reinforcer ratios out of 186 were omitted—one each for 3 pigeons and two for 1 pigeon). For each reinforcer ratio, overall reinforcer rate varied from about 10 to about 400 reinforcers per hour. Figure 3 shows the average results, which were representative of the results for the individual birds.

The top graph in Figure 3 shows the total rate of pecking at the two keys as a function of the overall reinforcer rate. The curve represents the least squares fit of Equation 4 ($r_0 = 9.44$; $k = 94.6$). The only unusual feature

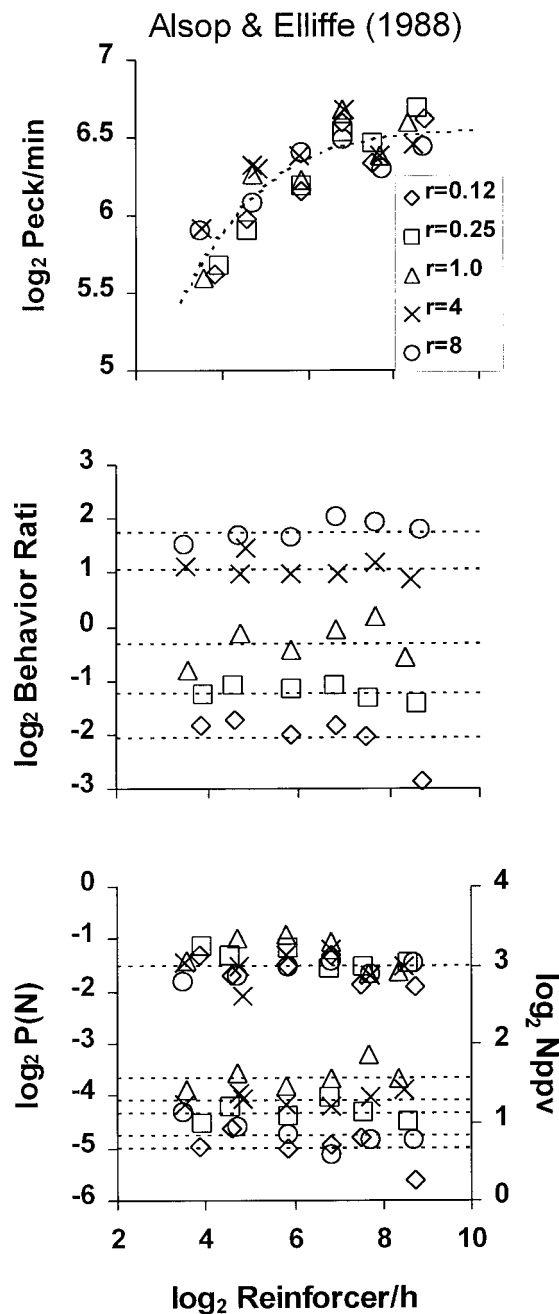


Fig. 3. A study of concurrent schedules that illustrates the concept of nested patterns. Top: combined rate of key pecking on two concurrent VI schedules as a function of overall rate of reinforcement. The different symbols represent different levels of reinforcer ratio (r). The curve represents the least squares fit of Equation 4 to all the points. Middle: relative responding at the two alternatives as a pattern nested within the pattern of overall rate of key pecking. The horizontal lines represent the average behavior ratio at each level of reinforcer ratio. Behavior ratio varies, as would be expected, across rein-

of this analysis is that pecks at the two keys were combined, whereas usually Equation 4 would apply to pecks at a single key. Recalling that Equation 4 describes choice between schedule-reinforced activity and other background activities, we see that choice between key pecking and other activities followed the orderly pattern expected from the matching law. That the various sets of symbols all overlap each other shows that reinforcer ratio had no effect on this choice pattern.

The middle graph in Figure 3 shows that the overall key pecking contained within it another regular pattern. Here the ratio of pecks at the two keys is plotted against overall reinforcer rate. As in the top graph, the different symbols represent data from the different reinforcer ratios from the two keys. A horizontal line, corresponding to the average peck ratio, is drawn through each set of symbols to allow assessment of trend. As overall reinforcer rate varied, each reinforcer ratio maintained a certain peck ratio, which remained approximately invariant across overall reinforcer rate. In other words, regardless of the overall rate of reinforcement, the behavior ratio remained about the same for each reinforcer ratio, in accordance with the generalized matching law (Equation 7).

The bottom graph in Figure 3 shows that, on still closer examination, a pattern exists within the behavior ratios, the activity that I earlier called fix and sample (Baum et al., 1999). To see whether such a pattern was present, I calculated for each behavior ratio the average number of pecks in a visit to the nonpreferred key and the probability of leav-

forer ratio, but is independent of overall rate of reinforcement. Bottom: the fix-and-sample pattern nested within the pattern of relative responding. The bottom five horizontal lines indicate the averages of probability of visiting the nonpreferred alternative, $p(N)$, across the levels of reinforcer ratio. The smaller the relative reinforcement for visiting the nonpreferred alternative, the lower the probability of visiting it. Hence, the symbols for r equal to 0.12 and 8.0 (circles and diamonds) show the lowest $p(N)$, and the symbols for r equal to 1.0 (triangles) show the highest $p(N)$. The uppermost horizontal line shows the average number of pecks per visit at the nonpreferred alternative (N_{ppv} ; right vertical axis). The average duration of a visit to the nonpreferred alternative remained approximately constant at eight pecks, consistent with the fix-and-sample pattern. All variables are transformed to Base 2 logarithms.

ing the preferred key to visit the nonpreferred key (number of visits to the nonpreferred key divided by number of pecks at the preferred key). The fix-and-sample pattern would be revealed by invariant visits to the nonpreferred key combined with variation only in the probability of visiting the nonpreferred key. For convenience, both probability of visiting the nonpreferred key [$p(N)$] and number of pecks per visit to the nonpreferred key ($Nppv$) are shown in the same graph; $p(N)$ is represented on the left vertical axis, and $Nppv$ is represented on the right vertical axis. The five lower sets of symbols show that $p(N)$, like the behavior ratio, differed across reinforcer ratios, but remained approximately invariant for each reinforcer ratio as overall reinforcer rate varied. Each reinforcer ratio produced a certain, roughly invariant, probability of a visit to the nonpreferred alternative. The horizontal lines show the averages. As would be expected from the results of Baum et al. (1999), the lowest probabilities of visiting the nonpreferred key occurred for the strongest preferences, generated by the most extreme reinforcer ratios (8 and 0.12). The two intermediate reinforcer ratios (4 and 0.25) produced intermediate $p(N)$, and the 1:1 reinforcer ratio, which produced the weakest preferences, produced the highest probabilities of visiting the nonpreferred side. The higher the relative reinforcement for the nonpreferred key, the higher the frequency of visiting the nonpreferred key. The uppermost sets of symbols show that $Nppv$, the visit duration to the nonpreferred key, remained invariant with respect to both overall reinforcer rate and reinforcer ratio. Independence from overall reinforcer rate is shown by the adherence of the points to the horizontal line representing the average. That the different symbols all lie on top of one another shows independence from the reinforcer ratio. Visits to the nonpreferred side, regardless of rate or distribution of reinforcement, always lasted about eight pecks (i.e., 2^3 ; see right vertical axis), presumably long enough to outlast the 2-s COD. Regardless of the behavior ratio, the same activity of briefly visiting (i.e., sampling) the nonpreferred key held; only the probability of visiting changed to produce the different behavior ratios shown in the middle graph.

Figure 3 shows how activities or patterns

may be nested within each other. Nested within the pattern of overall responding to the keys (top graph) was a pattern of allocation of the overall responding between the keys, measured by the behavior ratio (middle graph). Nested within the behavior ratio was a pattern of visitation at the two keys, a pattern of fixing on the preferred alternative and briefly sampling the nonpreferred alternative with a frequency depending on the reinforcer ratio (bottom graph). In the molar view, all of these patterns constitute allocations—between pecking and background activities (top graph), between pecking left and pecking right (middle graph), and between fixing and sampling (bottom graph).

CONCLUSION

An activity, like a species, is an individual, a concrete particular with parts, not a class with instances. Contrary to 19th- and early 20th-century thinking, the concrete particulars of behavior need not be momentary or discrete, but extend through time as parts of behavioral patterns (activities or allocations) over minutes, hours, days, or years. Like species, they only need to have a beginning and potentially an end. This recognition changes the notions of reinforcement and stimulus control, but only moderately. Instead of thinking of reinforcement as a sort of “moment of truth” (e.g., Ferster & Skinner, 1957; Skinner, 1948), defined by contiguity with a momentary response, we may think of reinforcement as a cumulative effect, as selection through time (Skinner, 1981; Staddon, 1973), shaping patterns of behavior (activities) in lineages. Because reinforcement operates on the activity as a whole, we are relieved of any need to imagine that the parts are all separately reinforced. Behavioral chains, for example, need not be held together with imagined conditional reinforcers, because they are reinforced as a whole (Baum, 1973; Rachlin, 1991). Avoidance need not be explained with imagined stimuli and reinforcers (Baum, 1973, 2001). We understand the behavior of a species in relation to the climate and resources available in its evolutionary environment. Similarly, instead of thinking of stimulus control as changing the probability of a response, we may think of discriminative stimuli as setting the context in which certain ac-

tivities or patterns are reinforced and wax in the time that they occupy. Making these extensions, we increase our ability to explain disparate phenomena, such as variation in asymptotic response rate (k), asymmetrical concurrent performances (Figure 1), resistance to change, and the relations among analyses at various levels of generality (Figures 2 and 3; Hineline, 2001).

Questions remain, of course. If an activity is an individual, how should we think about its coherence? Ghiselin (1997) explains that organisms have a special cohesiveness that species and other taxa lack; an organism functions as an integrated whole. The parts of a species may be less crucial than those of an organism, but a species has coherence because it is defined as a reproductive unit, reproductively isolated from other such units (Mayr, 1970) and because the parts of the species share common ancestry (i.e., are parts of the same lineage). Higher taxa, from genus on up, have coherence only because of common ancestry. In analogy to biological taxa, the parts of an activity share common ancestry—are parts of the same lineage—because they result from the same history of selection (reinforcement). The various parts of the activity we call “holding a job” cohere because they share a common function (gaining resources) and a common history of selection (reinforcement) among variants that functioned better and worse. Activities may become extinct in the same way as species, by a loss of functionality of the whole. The end of an unrewarding marriage (an activity) is the end of an individual, like the extinction of a species. Further evidence of coherence in the parts of an activity may be found in common variation in the face of change in environmental factors (Herrnstein, 1977). Food deprivation, for example, changes time allocation to a host of food-related activities. A more complete answer to the question of coherence awaits further research.

Although the research discussed here suggests advantages to the molar view over the molecular, deciding between the two paradigms depends, not on data, but on satisfactory interpretation of data. No one should doubt that molecular accounts of concurrent performance are possible. The advantages to the molar view lie in its ability to integrate experimental results, in its promotion of

quantitative theory, and in its applicability to everyday life. The results of Alsop and Elliffe (1988; Figure 3) illustrate the way the molar view both integrates results at various levels of analysis and fits them into a quantitative framework. The hypothetical example of Liz (Figure 2) illustrates the power of the molar view to apply to everyday concepts like “holding a job” or “recreation” (see Rachlin, 1994, for further discussion). Taking our cue from another historical science, evolutionary biology, we see that extendedness of allocations or activities in no way excludes them from concreteness. On the contrary, I have argued that the discrete events of the molecular view are abstractions (see Baum, 1997, for further discussion). Although someone committed to the molecular view might disagree, I have argued that on these grounds of plausibility, explanatory power, and elegance the molar view is the superior paradigm.

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